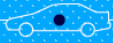




# McPherson strut side Force optimization using ADAMS/Chassis

Ramesh Edara  
Project Engineer  
ArvinMeritor Inc.

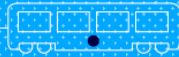
PRODUCT DEVELOPMENT CONFERENCE



# Presentation Outline

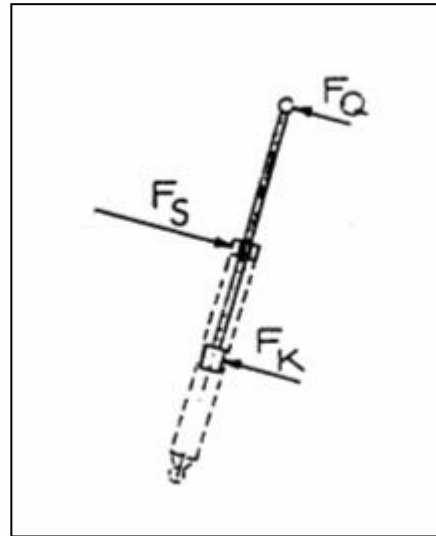
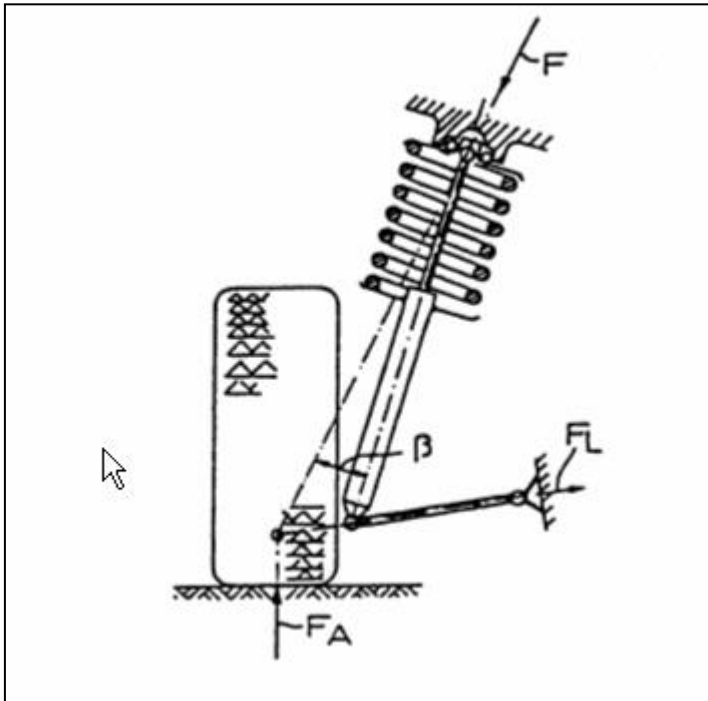
**ArvinMeritor™**

- ✓ • Introduction
- Input data for MSC.ADAMS Analysis
- MSC.ADAMS Analysis
- Results
- Conclusion

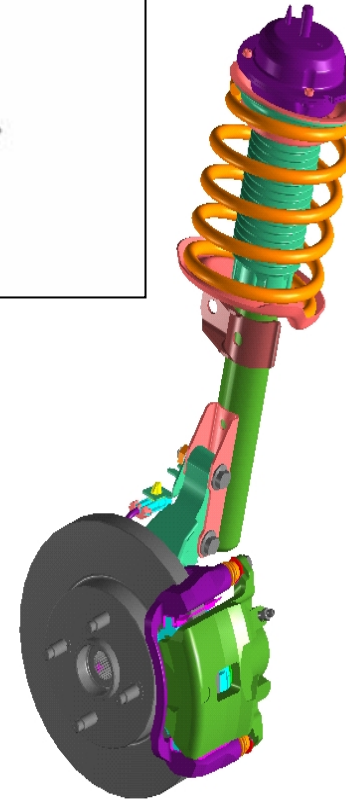


# Introduction

- Construction
- Strut Side Force

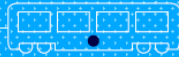


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TOP WORK

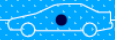
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# Presentation Outline

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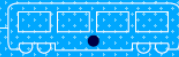
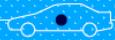
- Introduction
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# Input data

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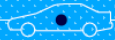
- Suspension geometry hard points
- Suspension bushings rates
- McPherson strut piston , rod guide locations
- Suspension static loads
- Coil spring end configurations
- Spring seat end configurations
- Packaging constraints



# Presentation Outline

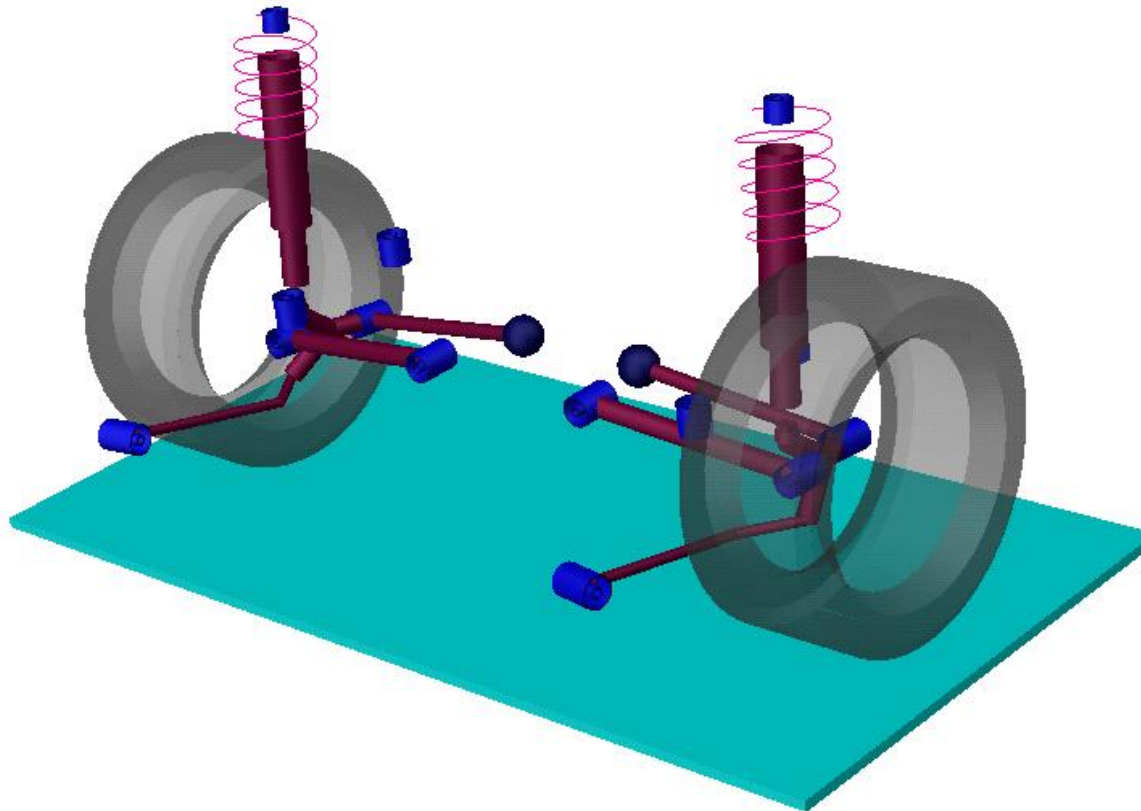
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- Conclusion



# MSC.ADAMS Analysis

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# MSC.ADAMS Analysis

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- Current design Side Force Estimation
- Screening DOE using MSC.ADAMS/Insight
- Study the sensitivity of parameters
- Effect of these factors on other suspension performance parameters
- Factorial DOE with interactions



## • **Current design Side Force Analysis**

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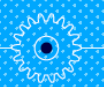
- Half vehicle Event
- Ride Motion Analysis
- Simple Bending strut
- Pierce point calculations (Coil end geometry)
- User Requests



# Presentation Outline

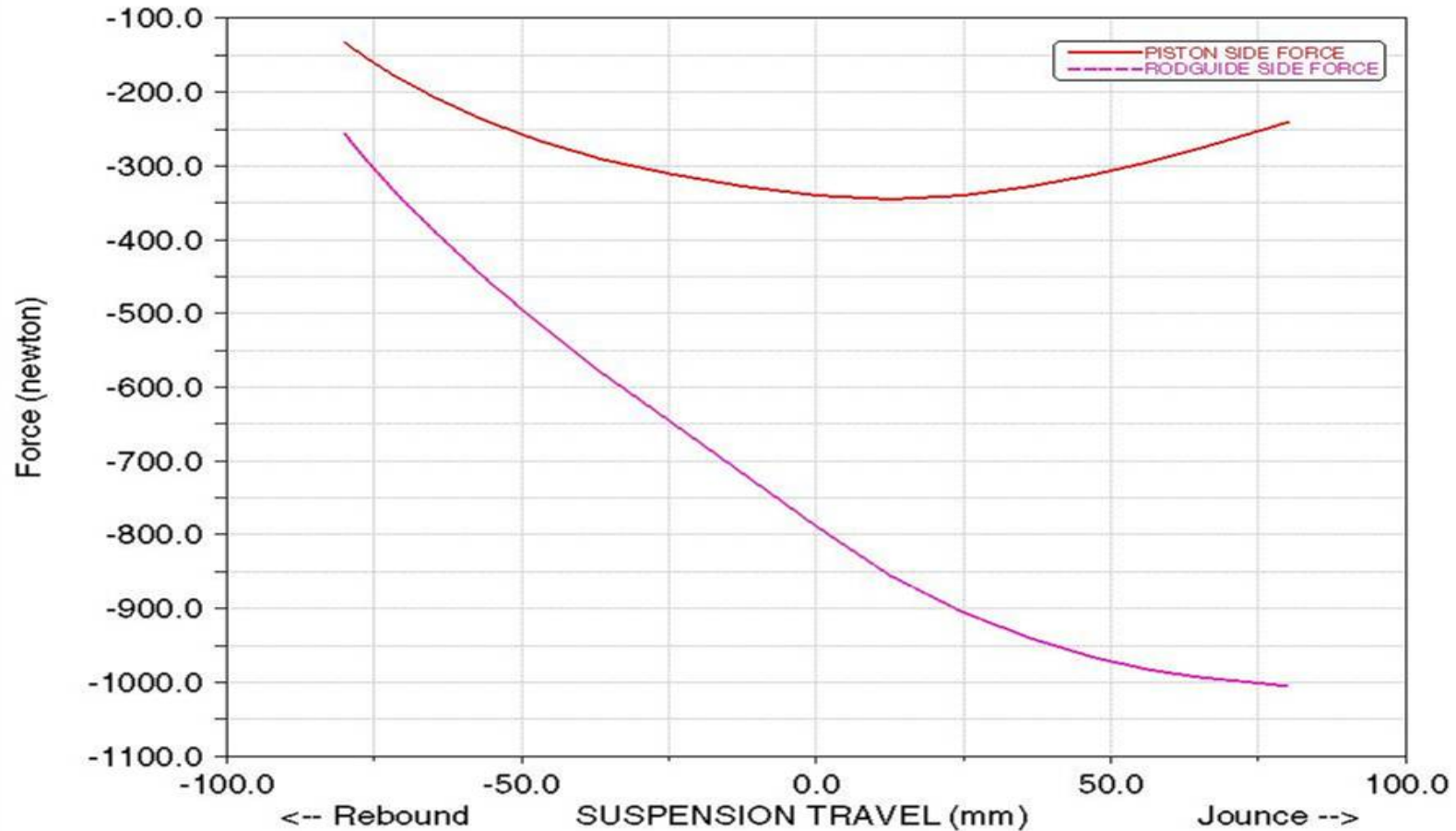
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- Input data for MSC.ADAMS Analysis
- MSC.ADAMS Analysis
- ✓ • Results
- Conclusion



# The Strut Side force –Original

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## • Screening DOE Analysis

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- Factors (18)
  - suspension geometry parameters
  - Bushing stiffness
  - Strut length
- Responses (2) –User defined
  - Piston Side Force
  - Rod Guide Side Force
- Levels (2)
- Experiment – Placket Burman (24)



# Identifying Important Factors

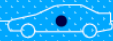


## Responses from Experiment "inv"

Factor	Units	Current	Tolerance	Min	Nominal	Max	Description
rear_suspension_d_car_rst_spring_seat_lower_left_x	mm	3.7451e+03	2.0000	3.7351e+03	3.7451e+03	3.7551e+03	Coil spring (low end knuckle) 59 left location
rear_suspension_d_car_rst_spring_seat_lower_left_y	mm	-6.3440e+02	2.0000	-6.4440e+02	-6.3440e+02	-6.2440e+02	Coil spring (low end knuckle) 59 left location
rear_suspension_d_car_rst_spring_seat_lower_left_z	mm	3.5000e+02	2.0000	3.4000e+02	3.5000e+02	3.6000e+02	Coil spring (low end knuckle) 59 left location
rear_suspension_d_car_rst_spring_seat_upper_left_x	mm	3.7651e+03	2.0000	3.7551e+03	3.7651e+03	3.7751e+03	Coil spring (top end frame) 58 left location
rear_suspension_d_car_rst_spring_seat_upper_left_y	mm	-6.1500e+02	2.0000	-6.2500e+02	-6.1500e+02	-6.0500e+02	Coil spring (top end frame) 58 left location

## Main Effects for Response: e\_001\_d\_car\_rear\_sys\_rride\_MIIN\_LR\_rodguide\_Y\_Force

Factor	From	To	Effect	Effect %
rear_suspension_d_car_rst_spring_seat_lower_left_y	-6.4440e+02	-6.2440e+02	4.3581e+02	65.43
rear_suspension_d_car_rst_spring_seat_upper_left_y	-6.2500e+02	-6.0500e+02	-2.9514e+02	-44.31
rear_suspension_d_car_rst_spring_seat_upper_left_z	5.5240e+02	5.7240e+02	-1.1917e+02	-17.89
rear_suspension_d_car_rst_spring_seat_lower_left_z	3.4000e+02	3.6000e+02	9.0385e+01	13.57
rear_suspension_d_car_rst_strut_mount_knuckle_left_z	7.2000	2.7200e+01	-7.6056e+01	-11.42
rear_suspension_d_car_rst_spring_seat_lower_left_x	3.7351e+03	3.7551e+03	3.1533e+01	4.73
rear_suspension_d_car_rst_strut_mount_knuckle_left_x	3.6925e+03	3.7125e+03	-3.0670e+01	-4.6
d_car_rst_shk_ssb_strut_mount_ktScaleFactor_y	-2.0000	4.0000	2.9800e+01	4.47
d_car_rst_shk_ssb_rodLength	3.3000e+02	3.5000e+02	-2.5920e+01	-3.89
d_car_rst_shk_ssb_strut_mount_ktScaleFactor_z	-2.0000	4.0000	-2.2633e+01	-3.4
d_car_rst_shk_ssb_strut_mount_krScaleFactor_x	-2.0000	4.0000	-2.1809e+01	-3.27
d_car_rst_strut_mount_bus_rz_stiffness_linear_data_rate	9.0000	1.1000e+01	1.4334e+01	2.15
d_car_rst_shk_ssb_strut_mount_krScaleFactor_z	-2.0000	4.0000	1.4187e+01	2.13
d_car_rst_shk_ssb_strut_mount_krScaleFactor_y	-2.0000	4.0000	-1.3389e+01	-2.01
d_car_rst_shk_ssb_topStrutLength	3.9420e+02	4.1420e+02	-1.2793e+01	-1.92
d_car_rst_shk_ssb_strut_mount_ktScaleFactor_x	-2.0000	4.0000	3.7475	0.56
rear_suspension_d_car_rst_spring_seat_upper_left_x	3.7551e+03	3.7751e+03	-2.5465	-0.38
rear_suspension_d_car_rst_strut_mount_knuckle_left_y	-6.2040e+02	-6.0040e+02	-2.6200e-01	-0.04



## • Factors affecting Piston Side Force

**ArvinMeritor™**

- Spring Seat Lower Y (OB)
- Spring Seat Upper Y (IB)
- Strut mount at Knuckle Z (Up)
- Spring seat Upper Z (Up)
- Spring seat Lower Z (Lower)

Main Effects for Response: e\_001\_d\_car\_rear\_sys\_rride\_MIN\_LR\_piston\_Sforce

Factor	From	To	Effect	Effect %
rear_suspension_d_car_rst_spring_seat_lower_left_y	-6.4440e+02	-6.2440e+02	2.1263e+02	69.34
rear_suspension_d_car_rst_spring_seat_upper_left_y	-6.2500e+02	-6.0500e+02	-1.4318e+02	-46.69
rear_suspension_d_car_rst_strut_mount_knuckle_left_z	7.2000	2.7200e+01	-7.1087e+01	-23.18
rear_suspension_d_car_rst_spring_seat_upper_left_z	5.5240e+02	5.7240e+02	-5.3477e+01	-17.44
rear_suspension_d_car_rst_spring_seat_lower_left_z	3.4000e+02	3.6000e+02	3.6239e+01	11.82
d_car_rst_shk_ssb_strut_mount_krScaleFactor_x	-2.0000	4.0000	-2.2047e+01	-7.19
d_car_rst_shk_ssb_topStrutLength	3.9420e+02	4.1420e+02	-2.0189e+01	-6.58
rear_suspension_d_car_rst_strut_mount_knuckle_left_x	3.6925e+03	3.7125e+03	-1.8620e+01	-6.07
d_car_rst_shk_ssb_rodLength	3.3000e+02	3.5000e+02	-1.6231e+01	-5.29
rear_suspension_d_car_rst_spring_seat_lower_left_x	3.7351e+03	3.7551e+03	1.5811e+01	5.16
d_car_rst_shk_ssb_strut_mount_ktScaleFactor_y	-2.0000	4.0000	1.4951e+01	4.88
d_car_rst_shk_ssb_strut_mount_ktScaleFactor_z	-2.0000	4.0000	-1.2493e+01	-4.07
d_car_rst_strut_mount_bus_rz_stiffness_linear_data_rate	9.0000	1.1000e+01	1.2184e+01	3.97
d_car_rst_shk_ssb_strut_mount_krScaleFactor_y	-2.0000	4.0000	-1.2041e+01	-3.93
rear_suspension_d_car_rst_strut_mount_knuckle_left_y	-6.2040e+02	-6.0040e+02	1.0728e+01	3.5
d_car_rst_shk_ssb_strut_mount_ktScaleFactor_x	-2.0000	4.0000	4.8663	1.59
rear_suspension_d_car_rst_spring_seat_upper_left_x	3.7551e+03	3.7751e+03	2.5752	0.84
d_car_rst_shk_ssb_strut_mount_krScaleFactor_z	-2.0000	4.0000	-8.7918e-01	-0.29

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## • Factors affecting Rod guide Side Force

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- Spring Seat Lower Y (OB)
- Spring Seat Upper Y (IB)
- Spring seat Upper Z (UP)
- Spring seat Lower Z (Lower)
- Strut mount at Knuckle Z (UP)

Main Effects for Response: e\_001\_d\_car\_rear\_sys\_rride\_MIN\_LR\_piston\_Sforce

Factor	From	To	Effect	Effect %
rear_suspension_d_car_rst_spring_seat_lower_left_y	-6.4440e+02	-6.2440e+02	2.1263e+02	69.34
rear_suspension_d_car_rst_spring_seat_upper_left_y	-6.2500e+02	-6.0500e+02	-1.4318e+02	-46.69
rear_suspension_d_car_rst_strut_mount_knuckle_left_z	7.2000	2.7200e+01	-7.1087e+01	-23.18
rear_suspension_d_car_rst_spring_seat_upper_left_z	5.5240e+02	5.7240e+02	-5.3477e+01	-17.44
rear_suspension_d_car_rst_spring_seat_lower_left_z	3.4000e+02	3.6000e+02	3.6239e+01	11.82
d_car_rst_shk_ssb_strut_mount_krScaleFactor_x	-2.0000	4.0000	-2.2047e+01	-7.19
d_car_rst_shk_ssb_topStrutLength	3.9420e+02	4.1420e+02	-2.0189e+01	-6.58
rear_suspension_d_car_rst_strut_mount_knuckle_left_x	3.6925e+03	3.7125e+03	-1.8620e+01	-6.07
d_car_rst_shk_ssb_rodLength	3.3000e+02	3.5000e+02	-1.6231e+01	-5.29
rear_suspension_d_car_rst_spring_seat_lower_left_x	3.7351e+03	3.7551e+03	1.5811e+01	5.16
d_car_rst_shk_ssb_strut_mount_ktScaleFactor_y	-2.0000	4.0000	1.4951e+01	4.88
d_car_rst_shk_ssb_strut_mount_ktScaleFactor_z	-2.0000	4.0000	-1.2493e+01	-4.07
d_car_rst_strut_mount_bus_rz_stiffness_linear_data_rate	9.0000	1.1000e+01	1.2184e+01	3.97
d_car_rst_shk_ssb_strut_mount_krScaleFactor_y	-2.0000	4.0000	-1.2041e+01	-3.93
rear_suspension_d_car_rst_strut_mount_knuckle_left_y	-6.2040e+02	-6.0040e+02	1.0728e+01	3.5
d_car_rst_shk_ssb_strut_mount_ktScaleFactor_x	-2.0000	4.0000	4.8663	1.59
rear_suspension_d_car_rst_spring_seat_upper_left_x	3.7551e+03	3.7751e+03	2.5752	0.84
d_car_rst_shk_ssb_strut_mount_krScaleFactor_z	-2.0000	4.0000	-8.7918e-01	-0.29

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- **Factorial DOE**

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- Factors (5)

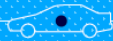
- Selected from Screening DOE
- Interactions included

- Responses (2) –User defined

- Piston Side Force
- Rod Guide Side Force

- Levels (2)

- Experiment – Fractional Factorial (16)



# • Effects – Based on Factorial DOE



Responses from Experiment "inv2"

Factor	Units	Current	Tolerance	Min	Nominal	Max	Description
rear_suspension_d_car_rst_spring_seat_lower_left_y	mm	-6.3440e+02	2.0000	6.4440e+02	6.3440e+02	6.2440e+02	Coil spring (low end knuckle) 59 left location
rear_suspension_d_car_rst_spring_seat_lower_left_z	mm	3.5000e+02	2.0000	3.4000e+02	3.5000e+02	3.6000e+02	Coil spring (low end knuckle) 59 left location
rear_suspension_d_car_rst_spring_seat_upper_left_y	mm	-6.1500e+02	2.0000	6.2500e+02	6.1500e+02	6.0500e+02	Coil spring (top end frame) 58 left location
rear_suspension_d_car_rst_spring_seat_upper_left_z	mm	5.6240e+02	2.0000	5.5240e+02	5.6240e+02	5.7240e+02	Coil spring (top end frame) 58 left location
rear_suspension_d_car_rst_strut_mount_knuckle_left_z	mm	1.7200e+01	2.0000	7.2000	1.7200e+01	2.7200e+01	Strut lower 36 left location

Main Effects for Response: e\_001\_d\_car\_rear\_sys\_ride\_MIN\_LR\_Piston\_Y\_Force

Factor	From	To	Effect	Effect %
rear_suspension_d_car_rst_spring_seat_lower_left_y	-6.4440e+02	-6.2440e+02	1.5425e+02	116.98
rear_suspension_d_car_rst_spring_seat_upper_left_y	-6.2500e+02	-6.0500e+02	-9.4318e+01	-71.53
rear_suspension_d_car_rst_spring_seat_upper_left_z	5.5240e+02	5.7240e+02	-8.2785e+01	-62.78
rear_suspension_d_car_rst_spring_seat_lower_left_z	3.4000e+02	3.6000e+02	7.6993e+01	58.39
rear_suspension_d_car_rst_strut_mount_knuckle_left_z	7.2000	2.7200e+01	-3.1608e+01	-23.97

Main Effects for Response: e\_001\_d\_car\_rear\_sys\_ride\_MIN\_LR\_Rodguide\_Y\_Force

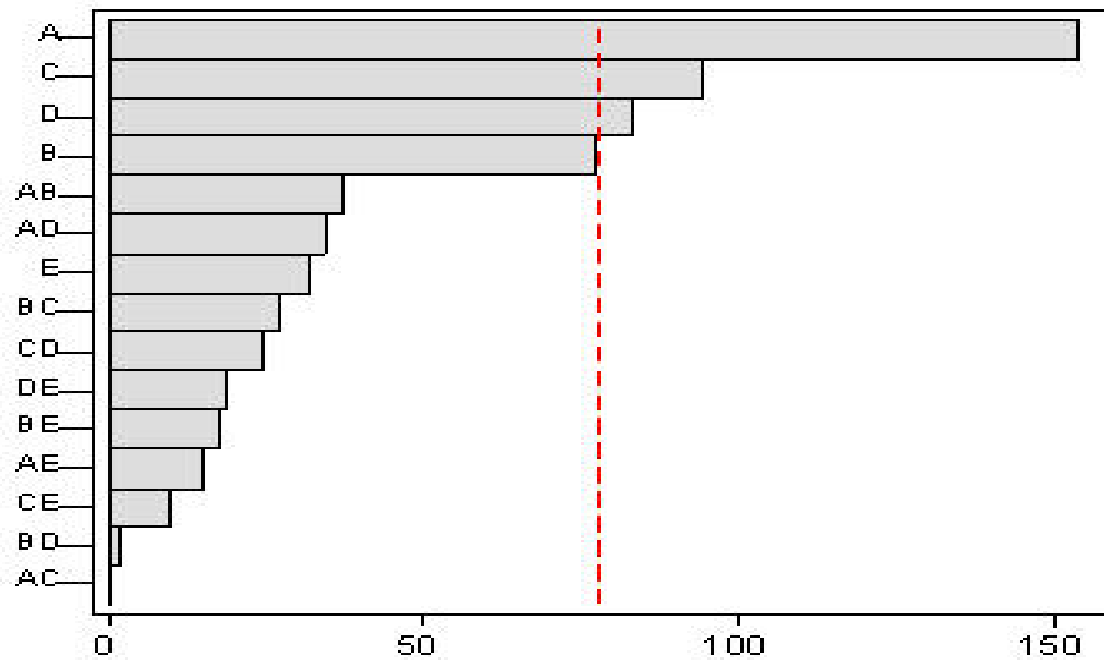
Factor	From	To	Effect	Effect %
rear_suspension_d_car_rst_spring_seat_lower_left_y	-6.4440e+02	-6.2440e+02	2.5809e+02	103.28
rear_suspension_d_car_rst_spring_seat_upper_left_y	-6.2500e+02	-6.0500e+02	-1.6081e+02	-64.35
rear_suspension_d_car_rst_spring_seat_upper_left_z	5.5240e+02	5.7240e+02	-1.3227e+02	-52.93
rear_suspension_d_car_rst_spring_seat_lower_left_z	3.4000e+02	3.6000e+02	1.2299e+02	49.21
rear_suspension_d_car_rst_strut_mount_knuckle_left_z	7.2000	2.7200e+01	-4.1679e+01	-16.68



# • Effects Ranking - Factors & Interactions



Pareto Chart of the Effects  
(response is Piston, Alpha = .10)



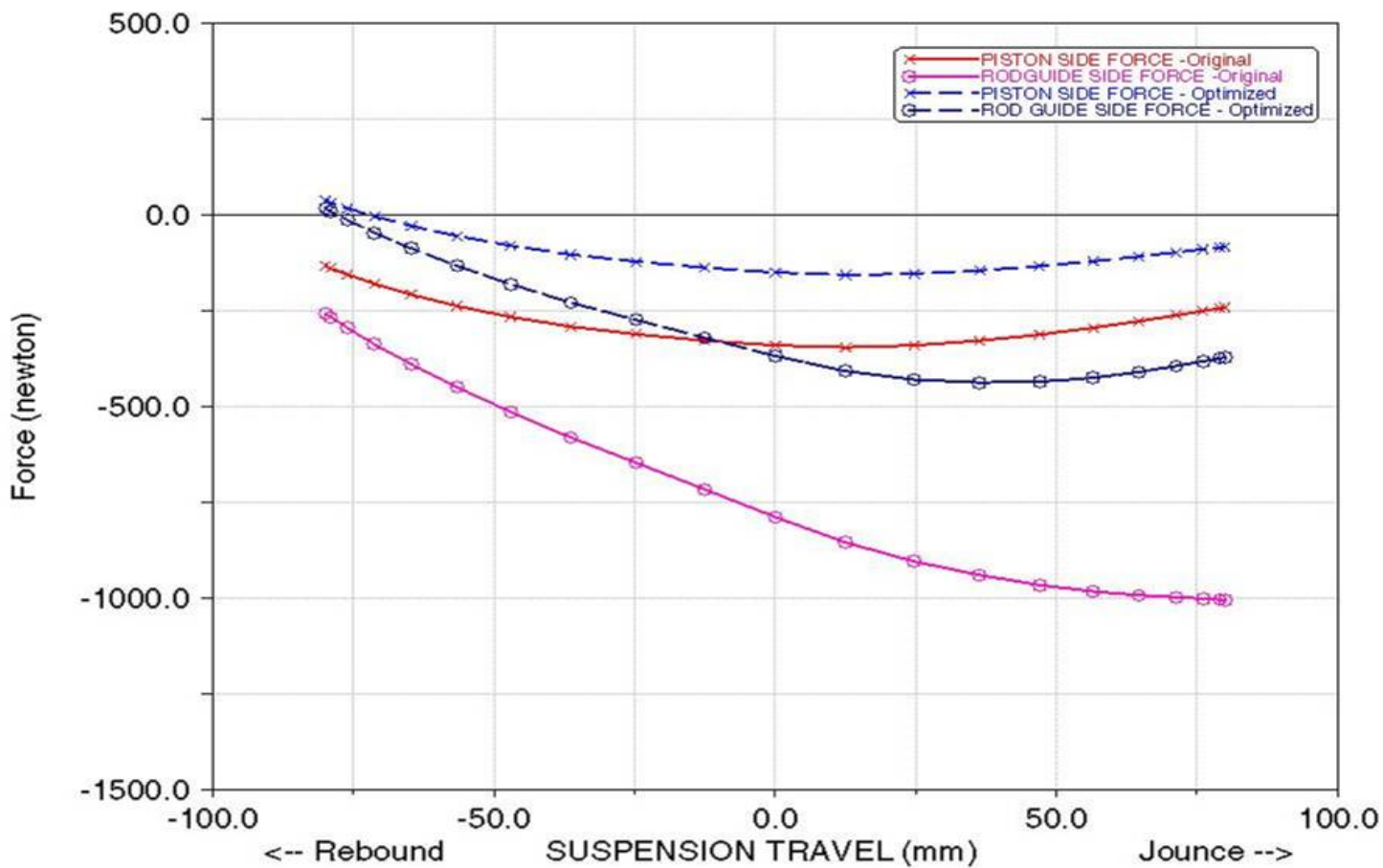


- **Selection of Optimum factors settings** *ArvinMeritor™*
  - 4 Significant Factors
  - The interactions are insignificant
  - Responses with optimum factors settings
  - Comparison of results



## • Comparison of Strut side Force

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# Presentation Outline

**ArvinMeritor™**

- Introduction
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- ✓ • Conclusion



# Conclusions

**ArvinMeritor™**

- The Strut side force is optimized using MSC.ADAMS
- DOE Studies are useful to identify significant factors
- Integration of ADAMS/CHASSIS and ADAMS/INSIGHT is useful for optimization studies